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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

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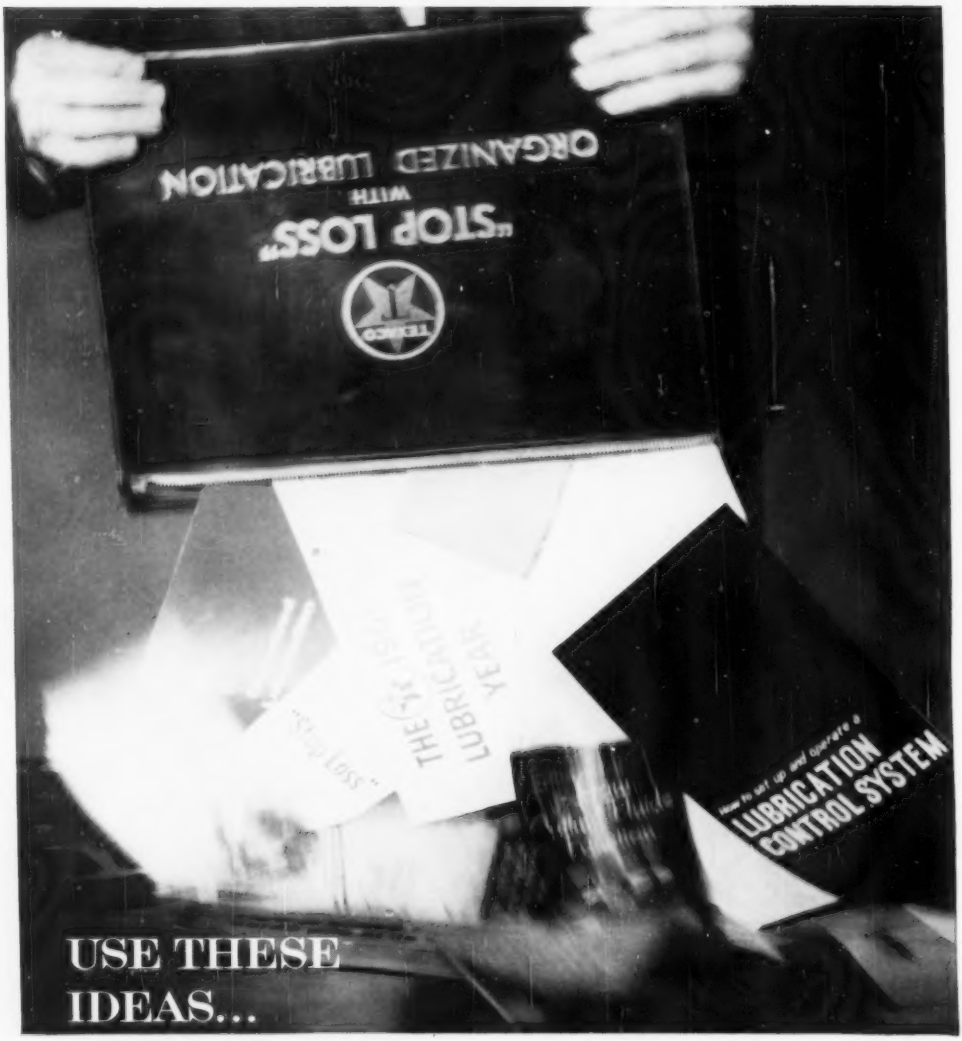

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

Published by

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GAS AND DUAL-FUEL ENGINES

OUR present day concept of an internal combustion engine is the result of inventions and developments made during the latter part of the 19th century. The major fundamental principle, which arose during this period, was that of applying compression to the gaseous charge. Originally, this was accomplished in the four stroke engine cycle as defined in the famous Otto patent of 1876. The pertinent extract from this patent is as follows:

"Compressing by one *in* stroke of the piston a charge of combustible and incombustible fluid drawn into the cylinder by the previous *out* stroke so that the compressed charge, when ignited, propels the piston during the next *out* stroke and the products of combustion are expelled by the next *in* stroke of the piston."

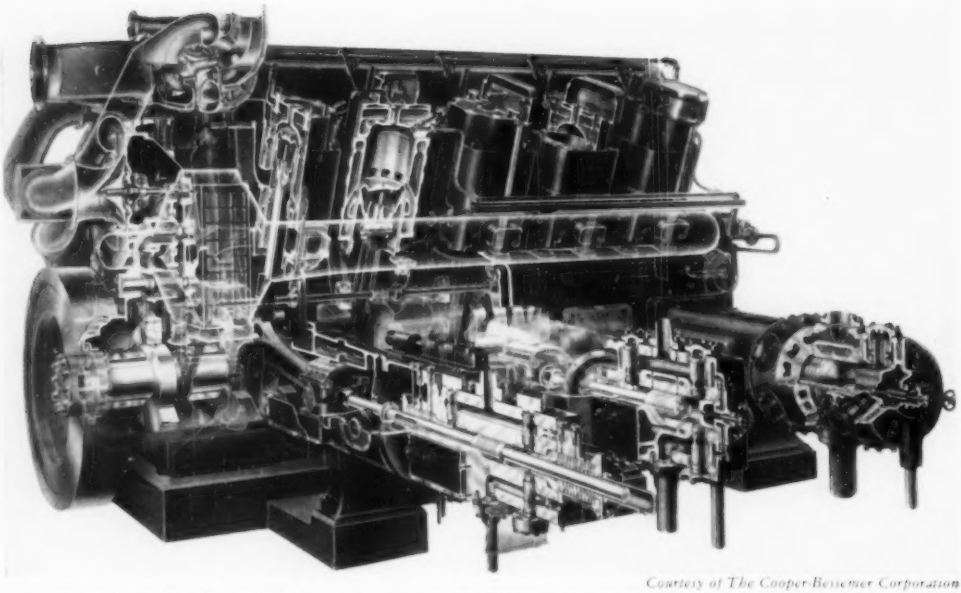
Nikolaus August Otto's interests in engines began when he was 21 years of age.[1] At that time the steam engine was for all practical purposes, the prime mover of the era. The Lenoir atmospheric gas engine was invented around 1860 and was proven to be both practical and successful. However, as the name implies the engine did not employ compression and accordingly, the efficiency was low. In effect the Lenoir engine was a converted steam engine, i.e., steam was replaced by the air-gas mixture.

[1] General information from January, 1961 issue "The Oil Engine and Gas Turbine."

During this period Nikolaus Otto began his experiments on improving the Lenoir atmospheric gas engine. By 1876 Mr. Otto was successful in applying his compression theory to the atmospheric gas engine and produced a working model. This was the birth of the modern four-cycle gas engine and, of course, the modern two-cycle variation of this basic principle, a good example of which is given in Figure 1.

Rudolf Diesel progressed the art by combining the gas engine with diesel operation, i.e., a dual-fuel engine. He applied for a patent along these lines in 1898, which in part stated, "the compression temperature of the working mixture does not reach its own ignition temperature, but the igniting temperature of a second, easier igniting fuel so that an injecting of the latter starts the combustion of the working mixture." Many years passed before such an engine was manufactured and placed in successful use.

In the United States gas engines have been used for many years as stationary power plants in areas where natural or manufactured gas has been available in large quantity. Until recently, however, these areas were confined primarily to the southern and western sections of the United States where low cost gas could be obtained from nearby refineries or gas and oil fields. A good example of such gas utilization is given in Figure 2 which shows a gas engine-compressor used in repressuring an oil field.



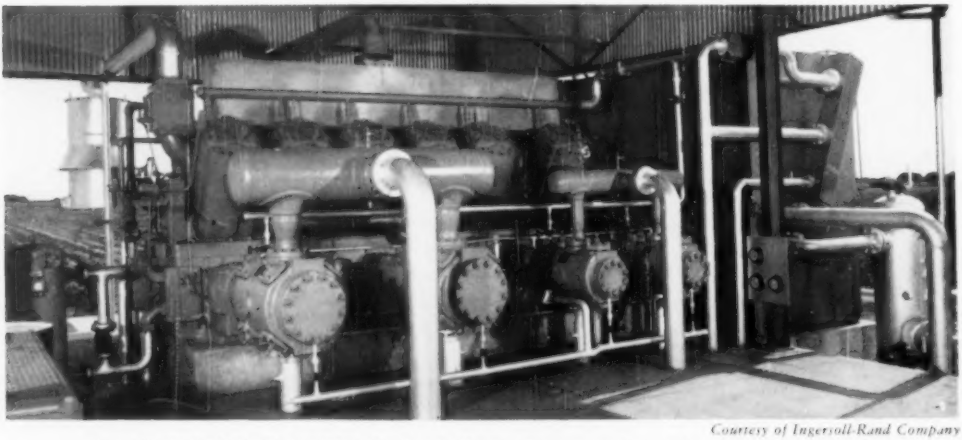
Courtesy of The Cooper-Bessemer Corporation

Figure 1—Model GMWC combined ten-cylinder vee type turbo-charged two-cycle gas engine and three stage compressor.

Figures 3 and 4 show two industrial type gas engines which are widely used to drive generators, pumps, and other stationery machines. Since the last war, the production and utilization of engines capable of burning gas, or a combination of gas and liquid fuel, have increased at a phenomenal rate. This is the result of the tremendous expansion of natural gas transmission to many parts of the country. These new transmission facilities have enabled the useful consumption of a natural resource that hitherto was not available where it was needed most, or was ignored or even wasted, and more and more gas engines like those shown in Figures 3 through 5 are now used for power sources.

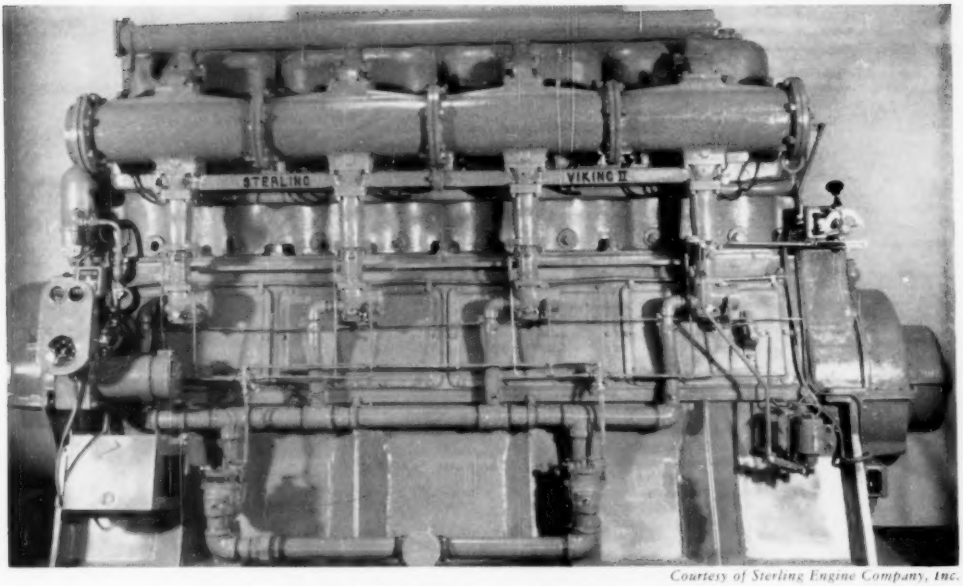
Gas engine sizes vary tremendously between the small gasoline adaptations shown in Figure 6 to the giants which are especially built for such purposes as pumping irrigation water, moving petroleum products through pipelines, or driving generators to provide electrical power to large cities.

Both the maximum power and efficiency of a given two or four-cycle engine can be increased



Courtesy of Ingersoll-Rand Company

Figure 2—Model 12-SVG-2 combined twelve-cylinder vee type gas engine and two-stage gas compressor.



Courtesy of Sterling Engine Company, Inc.

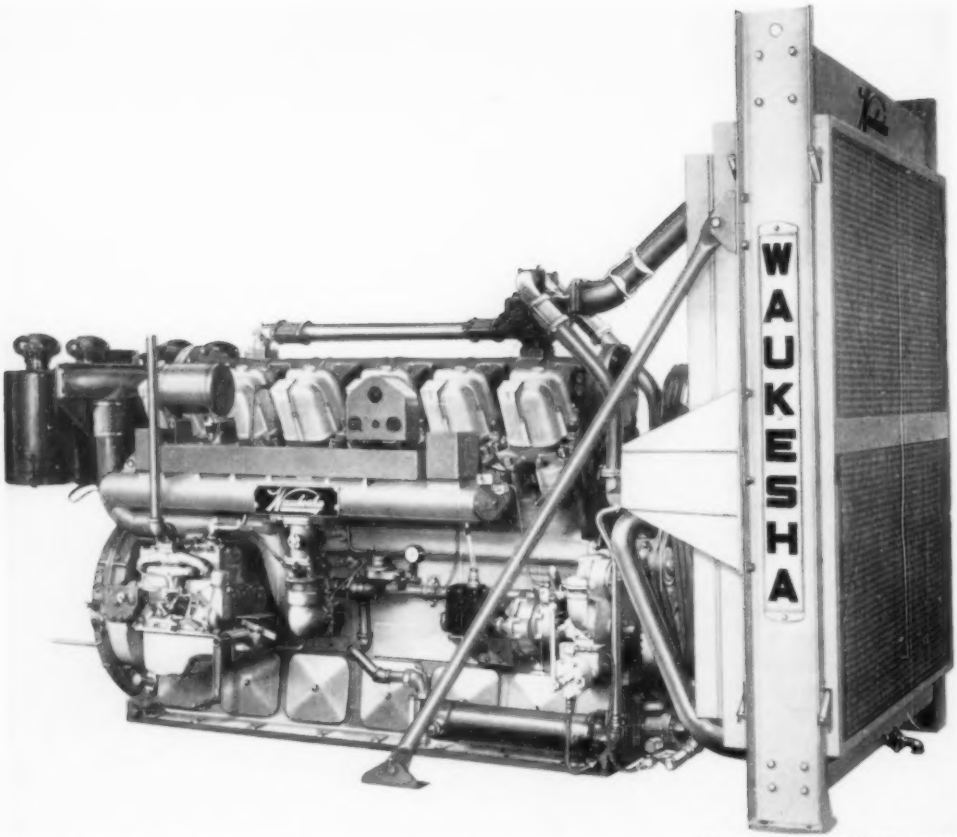
Figure 3—Model TC8 straight eight-cylinder industrial gas engine.

by "supercharging," i.e., by forcing in more air or air-gas mixture into each cylinder during its intake stroke than is "naturally aspirated" by piston movement. For this purpose, many large-engine manufacturers have adopted one or more "turbochargers" like that schematically illustrated in Figure 7 which utilize some of the otherwise-wasted energy in exhaust gases to drive an exhaust turbine and intake blower. Other manufacturers prefer a mechanically driven blower and at least one uses both types in the same engine as illustrated in Figure 1.

GASEOUS FUELS

From an operating standpoint the most interesting characteristics of a gaseous fuel are its heating value, the amount of air required for combustion, its anti-knock quality, its preignition tendency, the amount and nature of impurities and last but not least, its cost. Most engines operate on natural gas which is mainly composed of gaseous hydrocarbons such as methane and ethane with possible small percentages of propane and butane. Natural gas also contains minor percentages of other gases such as carbon dioxide, nitrogen or on occasion, hydrogen sulfide. Details of typical gas analyses are included in Table A. The usual natural gas will have a heating value of about 1,000 BTU per cubic foot and under ideal conditions would require about 10 cubic feet of air per cubic foot of gas for complete combustion. Actually, in regular engine operation, an excess of air is needed to insure complete combustion. While it is not practical to determine the anti-knock value of gaseous fuels under the prescribed standardized test conditions for liquid gasoline, it is recognized that the value for natural gas is well above 100 octane. In addition, such a fuel will not easily pre-ignite.

The type and character of undesirable products which may enter the engine with the fuel gas are varied as indicated in Table A. Natural gas as it issues from the well may be "wet," that is it may contain low-boiling liquid hydrocarbons. These components of "natural gasoline" are usually removed and recovered by traps in the pipe line, by passing the gas through absorption oil, or by compression and cooling. Wet gas entering an engine may cause sticking of the fuel (gas) valve as shown in Figure 8. Thus dry natural gas is comparatively clean although it may subsequently pick up rust particles from transmission piping. Illuminating or manufactured gas is likewise generally clean. Producer gas and coke-oven gas usually contain soot and tarry matter and the latter may also carry along with it some undesirable sulfur constituents. Blast furnace gas is almost always contaminated with lime dust, iron oxide and soot. Sewer gas, a by-product of sewage treatment, is basically methane but may contain a high percentage of hydrogen sulfide which can be removed by proper handling. Solid or gaseous impurities in gas can be eliminated, or at least reduced to a minimum, by scrubbing or water washing. Unless careful attention is accorded this operation, however, water may enter the engine along with the purified gas.



Courtesy of Waukesha Motor Company

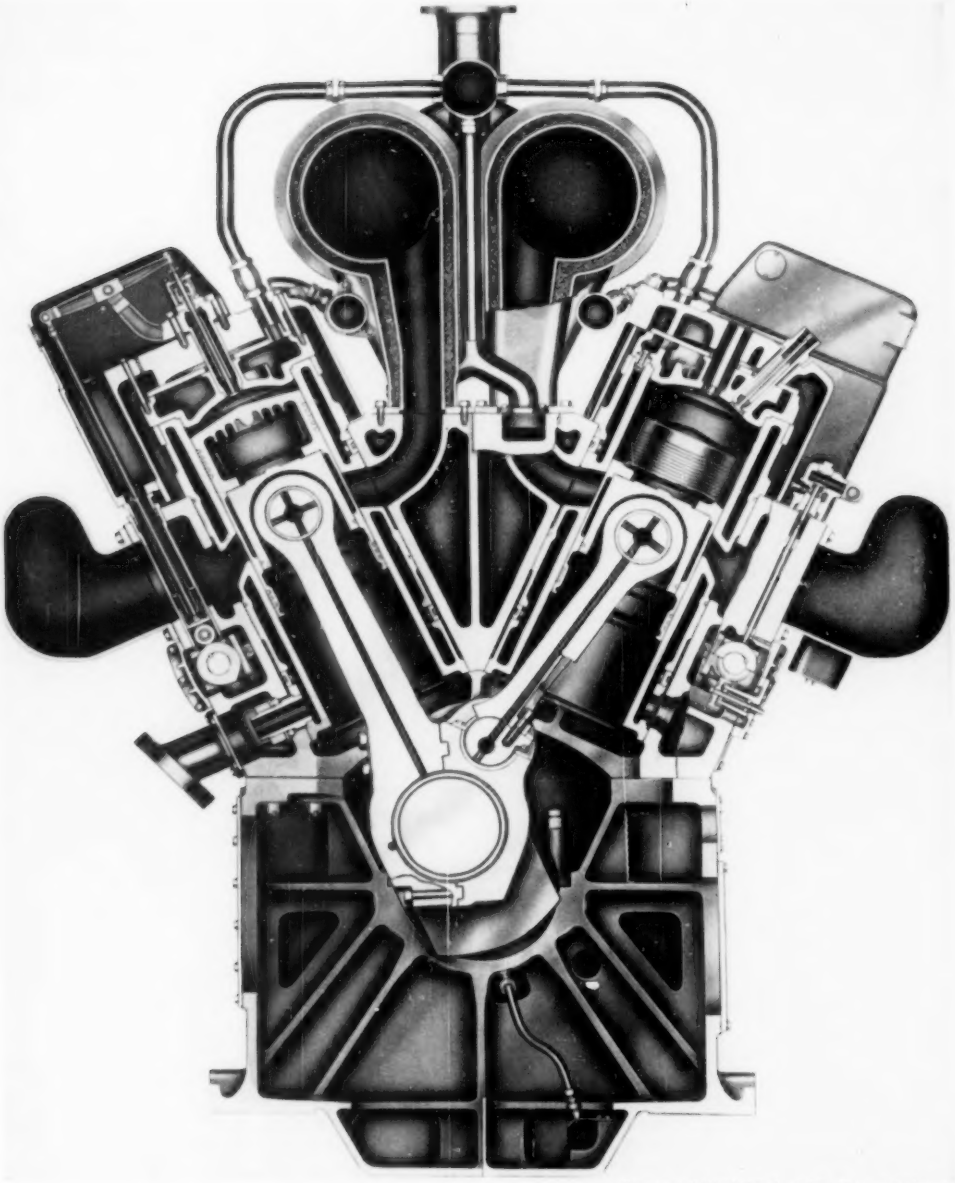
Figure 4—Model VLRO twelve-cylinder vee type industrial gas engine. Note four cylinder gasoline cranking engine at reader's left.

Experience has indicated that the composition of the gas has a considerable effect on the maintenance and lubrication aspect of an engine. As indicated in Table A, there are too many variables to be able to predict the performance to be obtained with any particular fuel. There seems to be evidence that a number of minor constituents (which may not even appear in the usual gas analysis) have a controlling effect on engine deposits and lubricant deterioration. Work is being done in this field and perhaps in the not too distant future an analysis by one of the new complex modern methods may be helpful in predicting the behavior of a gaseous fuel.

Liquefied Petroleum Gases

Although natural gas is used predominantly because of low cost, there are certain locations where liquefied petroleum gases (LPG) have been used in internal combustion engines. In the automotive field, engine conversions to this type of power were reported more than 20 years ago. However, in the last 10 years a large increase in the use of LPG has occurred and wide interest on the subject has resulted. Two typical small-engine LPG installations have been shown in Figure 6. In the small engine field, the interest was undoubtedly greatly spurred by a bus manufacturer whose engine was designed for high compression ratios and was easily modified to utilize propane. Conversion kits are now available for many makes of automotive engines, although compression ratios of most engines cannot be increased enough to obtain full advantage of the high octane of propane. In the truck, bus, and tractor fields, engine modifications for the use of butane and propane have been available for quite some time. As a matter of fact, a number of truck and tractor manufacturers are producing LPG burning engines as part of their line.

LPG has also become a popular "standby" fuel

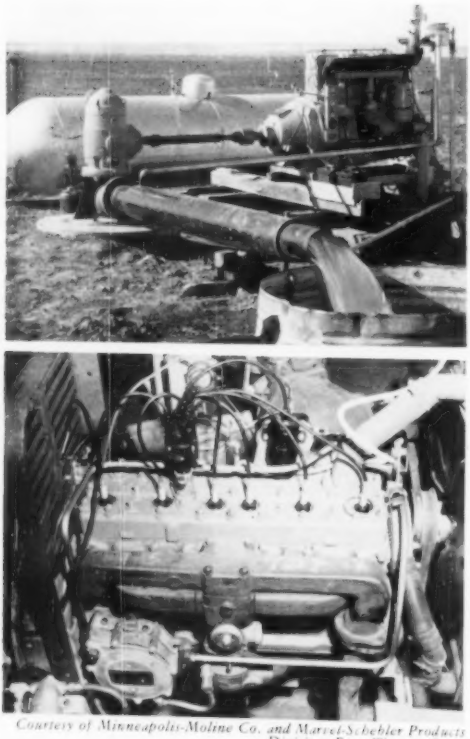


Courtesy of Clark Brothers Co., Dresser Industries

Figure 5—Cross section of Model TPV turbo-charged two cycle gas engine rated at 6400 BHP.

for many natural gas engine installations. This is particularly true for installations along a transmission line, where special "surplus" gas rates are given only during "off-peak" operation of the gas line. Under such a system, when the normal demand on a pipe line is high, special rate consumers must either shut down or switch to a standby fuel source such as LPG.

In general LPG is predominantly a mixture of propane (C_3H_8) and butane (C_4H_{10}) gases with



Courtesy of Minneapolis-Moline Co. and Marvel-Schebler Products Division, Borg-Warner Corp.

Figure 6—Typical industrial stationary engines adapted to burn LPG (liquefied petroleum gas).

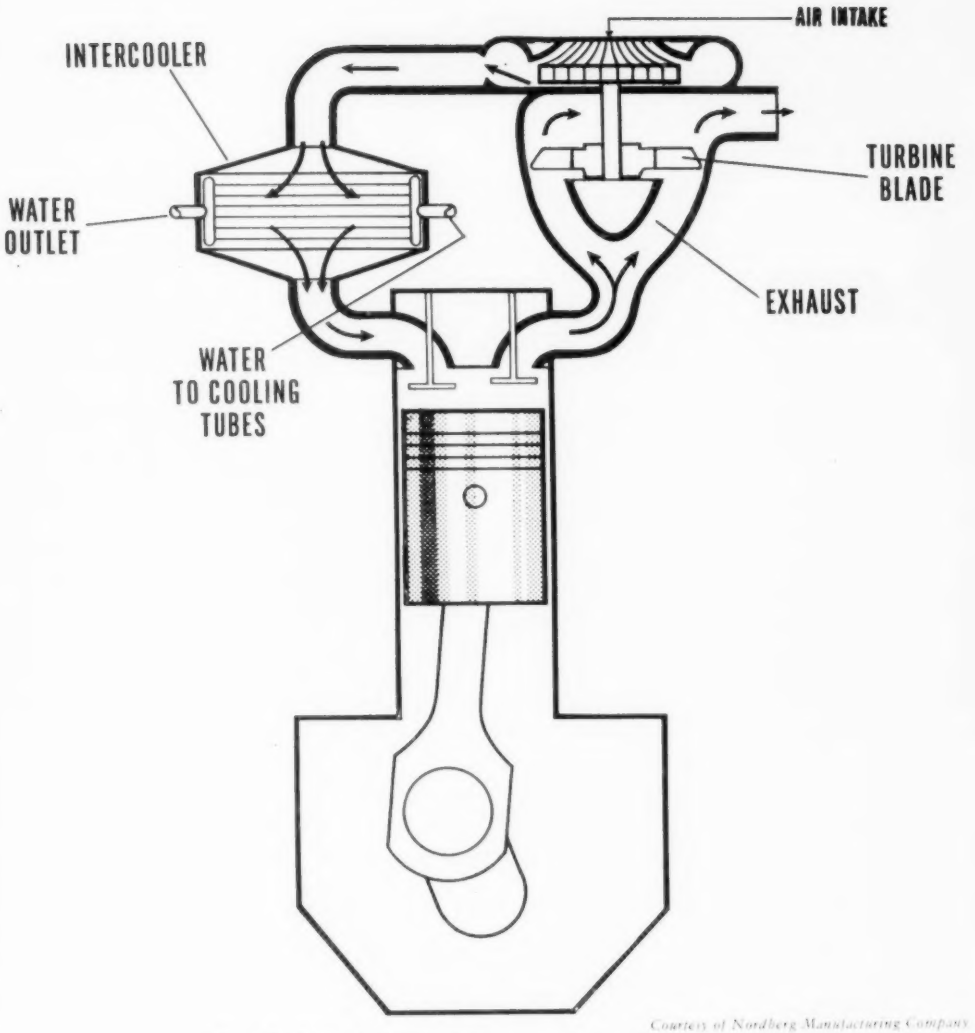
minor amounts of other hydrocarbon gases and perhaps very small amounts of the heavier C_5 liquid hydrocarbons (5 carbon atoms per molecule). Table B presents commercial specifications on propane, butane and blends thereof. When these gases are pressurized sufficiently they assume a liquid state which is much more compact and more suitable and economical for handling. The amount of pressure required for liquification varies with the composition, and at least this pressure must be maintained subsequently to keep the mixture in the liquid state. These gases, as obtained in a natural state or from petroleum refining processes, may contain impurities such as sulfur compounds and other contaminants which may be injurious to engine parts. The engine operator who uses LPG should have some assurance that these contaminants are minimized and that the composition of the fuel is relatively constant since propane and butane have somewhat different characteristics. At temperatures below 31° F. at standard atmospheric pressure, butane is normally in a liquid state and does not vaporize quickly enough to respond to engine demands. This fuel would be of little use to an engine equipped with a gas type carburetor at temperatures below 31°F. unless a means of heating the fuel is provided. An easier solution would be to include some lighter gas like propane to lower the boiling point and increase vaporization of the fuel. In view of the low vapor pressure of butane it might be assumed that a lighter fuel tank (lower pressure) might be used, however, for safety reasons it is wisest to use tanks able to sustain the worst pressure condition encountered which would be provided by pure propane.

For practical reasons LPG is normally carried and stored under pressure in the liquid state, however, it can only be burned in the vapor state. Pressures in the fuel tank are too high to be applied directly to a carburetor, furthermore adequate heat must be applied to the liquid fuel to completely vaporize it before entering the carburetor. The transfer of fuel from the tank to the engine is usually done in four stages, as shown in Figure 9. The tank pressure of from 20 to 175 psi. must first be reduced to a regulated 4 to 10 lbs. The fuel is then allowed to vaporize rapidly. Heat for the vaporizer is easily supplied from the engine coolant though in some "reefer" (refrigerated) trucks the boiling LPG is first used as a refrigerant in the truck body. The pressure of the vaporized fuel must then be further reduced to that of the natural gas in a gas conversion unit or to slightly below atmospheric if the engine is of the naturally aspirated carburetor type.

When converting a natural gas engine to the use of LPG some engine adjustments will be necessary. Propane and butane have much higher heat contents per cubic foot than natural gas, and accordingly, mixture ratio and spark timing should be altered to obtain optimum performance and economy. From the nature of LPG it might be expected that combustion would be so complete that no engine deposits, no cylinder wall washing and no crankcase contamination would occur. In practice, however, complete combustion is not always attained and partial-combustion by-products do enter the crankcase as blow-by material. Unless combustion is very poor and blow-by excessive, the quantity of these by-products should not materially increase engine deposits. However, butane and propane are straight-chain hydrocarbons, consequently the type of incomplete combustion materials formed and entrained in the lubricating oil can corrode certain alloy bearings. If an LPG engine is equipped with alloys susceptible to corrosion, a high quality heavy duty oil should be used to protect them.

DUAL-FUEL OPERATION

The terms "dual-fuel engine" and "gas-diesel engine" are used interchangeably to describe a compression-ignition engine which can operate either on a combination of gas with diesel fuel "pilot oil" for ignition, or as a full diesel engine using oil



Courtesy of Nordberg Manufacturing Company

Figure 7—Schematic diagram of a turbo super-charged four cycle engine.

only. Representative and widely used dual-fuel engines are shown in Figures 10 through 15.

When operating on gas plus pilot oil, the ratio of the two fuels can be adjusted over a relatively large range. The proportion of oil may vary from a low of about 5 to 7% (for pilot ignition) to 100% (full diesel operation). Figures 16 and 18 illustrate typical mechanisms used to control the oil-gas fuel mixture; these frequently include devices to stop the engine if it attempts to overspeed or if either lubricating oil, or gas or diesel fuel pressure drops below preset minimums. The flexibility of the dual-fuel engine is particularly desirable when the availability of gas is limited at certain periods. In this case the load requirement can be made up by burning additional diesel fuel.

It is possible to convert some makes and types of gas engines to dual-fuel engines or to full diesel engines. Likewise, some diesel engines can be altered to operate as dual-fuel engines or even as gas engines.

Since pilot oil is required for purposes of ignition, its most important characteristic is ignitability or cetane number. High cetane number will eliminate starting difficulties and misfiring and insure minimum gas consumption.

TABLE A, Typical Gas Analyses
Courtesy of American Gas Association

No.	Type	Source	Constituent Gases, per cent by volume										Specific Gravity	B.t.u. per Cu. Ft. Gross	B.t.u. per Cu. Ft. Net
			Co_2	O_2	N_2	CO	H_2	CH_4	C_2H_6	C_3H_8	C_4H_{10}				
1	Natural	Birmingham, Ala.			5.0			90.0	5.0				0.60	1002	904
2	Natural	Pittsburgh, Pa.			0.8			83.4	15.8				0.61	1129	1021
3	Natural	Los Angeles, Calif.	6.5					77.5	16.0				0.70	1073	971
4	Natural	Kansas City, Mo.	0.8		8.4			84.1	6.7				0.63	974	879
5	Natural	Reported by Ley	0.5		12.8			72.3	14.4				0.68	990	896
6	Natural	Dry type	0.2		0.6			99.2					0.56	1007	906
7	Natural	Wet type	1.1					87.0	4.1	2.6	2.0	C_5H_{12} 3.4	0.71	1223	1109
8	Natural	Sweet type			2.8			73.1	23.8				0.68	1166	1056
9	Natural	Sour type					H_2S 6.4	58.7	16.5	9.9	5.0	C_5H_{12} 3.5	0.92	1489	1359
10	Natural	Casinghead type						36.7	14.5	23.5	14.9	C_5H_{12} 10.4	1.29	2133	1953
11	Propane	Commercial (natural gas)							2.2	97.3	0.5		1.55	2558	2358
12	Propane	Commercial (refinery gas)							2.0	72.9	0.8	C_3H_6 24.3	1.77	2504	2316
13	Butane	Commercial (natural gas)								6.0	94.0[c]		2.04	3210	2961
14	Butane	Commercial (refinery gas)								5.0	66.7[b]	C_3H_6 28.3	2.00	3184	2935
15	Butane-air										17.2 (illuminants)	Air 82.8	1.16	550	516
16	Refinery oil	Liq. phase crack. (Cross)[a]		0.2	0.6	1.2	6.1	4.4	72.5				1.00	1650	1524
17	Reformed natural	Straight shot generator	2.1	0.3	1.5	13.6	48.3	33.0			1.2		0.41	559	497
18	Reformed natural	Water gas generator	1.2	0.1	3.8	22.3	49.8	21.9			0.83		0.44	464	424
19	Refinery oil	Vapor phase crack.	0.2	0.2	0.5	1.2	13.1	23.3	21.9		39.6		0.89	1475	1351
20	Reformed refinery oil		2.3	0.7	4.9	20.8	49.8	12.3	5.5		3.7		0.51	530	475
21	Oil gas	Portland	1.2	0.5	2.4	7.7	54.2	30.1			3.9		0.37	570	510
22	Coal gas	Horizontal retort	2.4	0.8	11.3	7.4	48.0	27.1			3.0		0.47	542	486
23	Coal gas	Inclined retort	1.7	0.8	8.1	7.3	49.5	29.2			3.4		0.47	599	540
24	Coal gas	Contin. vert.	3.0	0.2	4.4	10.9	54.5	24.2			2.8		0.42	532	477
25	Coal gas	Inter. vert.	1.7	0.5	8.2	6.9	49.7	29.9			3.1		0.41	540	482
26	Coal gas	Inter. vert. chamber	2.1	0.4	4.4	13.5	51.9	24.3			3.4		0.42	520	466
27	Coke oven	By-product	2.0	0.03	4.8	5.5	51.9	32.3			3.2		0.40	569	509
28	Producer	Buckwheat anthr.	8.0	0.1	50.0	23.2	17.7	1.0					0.86	143	133
29	Producer	Bituminous	4.5	0.6	50.9	27.0	14.0	3.0					0.86	163	153
30	Producer	Coke+0.6 lb. steam	6.4		52.8	27.1	13.3	0.4					0.88	135	128
31	Blast furnace		11.5		60.0	27.5	1.0						1.02	92	92
32	Blue gas	Coke	5.4	0.7	8.3	37.0	47.3	1.3					0.57	287	262
33	Blue gas	Bituminous	5.5	0.9	27.6	28.2	32.5	4.6			0.7		0.70	260	239
34	Carburetted water	Low gravity backrun	3.6	0.4	5.0	21.9	49.6	10.9	2.5		6.1		0.54	536	461
35	Carburetted water	Heavy oil with blow run	6.0	0.9	12.4	26.8	32.2	13.5			8.2		0.66	530	451
36	Carburetted water		4.3	0.7	6.5	32.0	34.0	15.5			7.0		0.67	534	493
37	Carburetted water	High B.t.u.	0.7	0.3	5.8	11.7	28.0	36.1			17.4		0.63	840	770
38	Sewage	Decatur, Ill.	22.0		6.0		2.0	68.0					0.73	690	621

No. 1– 4—Are average compositions as served to customers in cities named.
5–10—Ley, "Geology of Natural Gas," p. 1075.
11–14—Private Communication; Mattocks, Philgas Co.
15 —Handbook of Butane and Propane Gases.
16 —Gas Engineers' Handbook, p. 171.
17 —"Natural Gas," May 1929, p. 566.
18 —A.G.A. Proc., 1935, p. 781.
19 —Gas Engineers' Handbook, p. 171.
20 —E. L. Hall, U.G.I. Co.
21 —Portland Gas and Coke Co.
22–25—"Combustion," Third Edition, A.G.A.
No. 26 —Average data 30 days. United Engineers & Constr.
27 —H. C. Porter, Coal Carbonization, p. 313.
28–31—"Combustion," Third Edition, A.G.A.
32 —W. R. Morris, A.G.A. Proc. 1922, pp. 21-52.
33 —E. L. Fisher, A.G.A. Proc., 1929, Reversed Air-Blast Process.
34 —A.G.A. Proc., 1930, pp. 1490-1502.
35 —A.G.A. Proc., 1930, p. 1335.
36 —"Combustion," Third Edition, A.G.A.
37 —A.G.A. Proc., 1934, p. 929.
38 —Private memorandum; Morse Boulger Destructor Co.

[a] Dubbs process produces less illuminants (6.7%) and 65% CH_4 and 16% C_2H_6.
[b] Divided 16.5% isobutane, 50.1% n-butane.
[c] Divided 23.3% isobutane, 70.7% n-butane.

LUBRICATION

The lubrication systems of gas and gas-diesel or dual-fuel engines are very much the same. With the smaller engines used for pumping, auxiliary and automotive services, and for some of the larger engines, a lubrication system using one lubricant and combining both pressure and splash lubrication is invariably used. A schematic diagram of such a complete lubrication system is given in Figure 17.

For most of the larger engines, however, dual

TABLE B

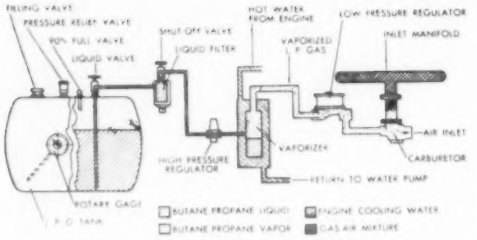
Liquefied Petroleum Gases, Specification Based on N. G. A. A. Specifications, June, 1951

Composition	Commercial Propane 95% minimum propane and/or propylene free from harmful quantities of deleterious substances.	Commercial Butane Approximately 95% minimum butane and/or butylenes free from deleterious substances.	Propane-Butane Mixtures Mixtures of propane and/or propylene and butane and/or butylene predominantly free from deleterious substances.
Vapor Pressure psi @ 100° F.	215 max.	70 max.	215 max.
Total Sulfur, (lamp) grains/100 cu. ft.	15 max.	15 max.	15 max.
H_2S (Hydrogen Sulfide)	None	None	None
Corrosion, Copper Strip 3 Hours @ 122° F.	Negative	Negative	Negative
Water, % (Cobalt Bromide)	None	None	None
95% Boiling Point (95% Evaporated) °F. @ 740 mm Hg barometer	—	34 max.	34 max.
Designation	—	—	By vapor pressure at 100° F. in psi gage.
Residue, % (Mercury Freeze Test)	2 max.	—	—

lubrication systems using two lubricants (or two supplies of the same lubricant) are generally necessary. In these the crankcase employs one lubrication system while the cylinders with their pistons and rings are separately lubricated through forced-feed sight-glass lubricators. In some instances "used" crankcase oil is fed to the sight feed lubricators. Water or mixtures of water and glycerine are the most common fluids used in sight glasses of cylinder lubricators. Glycerine is used where ambient temperatures may drop below the freezing point of water. Straight mineral oils can be fed through water and water-glycerine solutions for long periods of time without undue carryover of the solution. The same does not always hold true when additive oils, particularly those containing detergent or dispersant components, are used for cylinder lubrication. Additives used in such oils make the oils more water sensitive than straight mineral oils. This means that heavy duty detergent oils when fed through water or water-glycerine solutions in sight feed lubricators can result in any one or all three of the following effects:

1. Excessive carryover of solution due to absorption of the oil as shown in Table C.
2. Clouding of the solution due to reaction with the oil additives.

Figure 8—Stuck fuel (gas) valve caused by carbonization of liquid constituents in wet natural gas.



Courtesy of Ensign Carburetor Co., American Bosch Arma Corp.

Figure 9—Schematic flow diagram, method of supplying LPG fuel to an engine.

3. Larger oil drop size due to lower interfacial tension between the solution and oil as shown in Table D.

TABLE C
Sight Feed Lubricator Tests
Heavy Duty Oil A

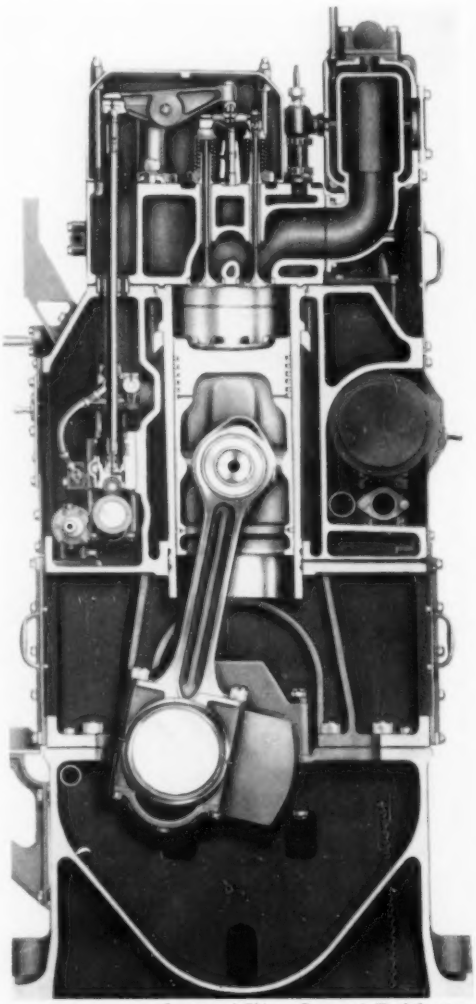
Solutions	*Solution Carryover inches/100 hours*
Water	0.371
Calcium chloride	0.195
Sodium chloride	0.438
Calcium Nitrate	0.115
Ethylene Glycol	1.228
Barium chloride	0.127
50:50 glycerine and water	6 (Approx.)

It is evident from the foregoing that feeding additive oils, containing detergents, through sight glass lubricators poses a problem for operators of large engines. Certainly, it is a time-consuming job to have to remove and clean numerous small sight glasses more often than necessary to say nothing of the down time on the engines involved. Such a problem is not difficult to solve, however, and lubricator solutions have been found which will provide the desired services for particular additive oils. Unfortunately, no one lubricator solution has been discovered that will work acceptably with all makes and types of additive oils. In addition, it does not appear probable that such an "ideal" solution will ever be developed in view of the great variety of chemicals that are and will be used in additive oils of the heavy-duty type.

In all types of lubrication systems, the crankcase oil is subject to contamination from gases and other materials which blow by the piston. These gases, in addition to containing dirt from the atmosphere, contain products of incomplete fuel combustion. In order to eliminate some of the gross contamination, the lubrication system contains provisions for filtering. The filtering system may be purely a micronic type filter which removes certain particle size agglomerated materials, or a purifying type filter of the activated type which in addition to removing gross contamination, may remove certain acid-bear-

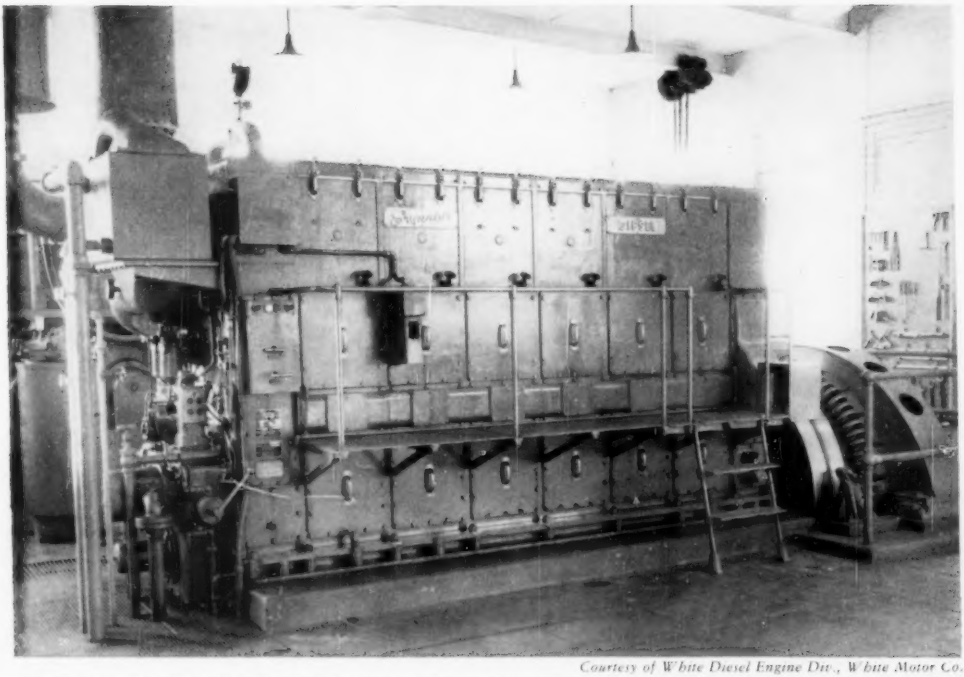
TABLE D
Interfacial Tension Data

Product (SAE 30 Grade)	*Interfacial Tension dynes/centimeter*
Heavy Duty Oil A	5.3
Heavy Duty Oil B	10.6
Straight Mineral Naphthene	31.6
Straight Mineral Paraffin Residual	36.5
Straight Mineral Paraffin Distillate	39.4



Courtesy of Chicago Pneumatic Tool Company

Figure 10—Cross section, Model 112-CP naturally-aspirated four cycle dual fuel engine. Note use of dual exhaust (and intake) valves.

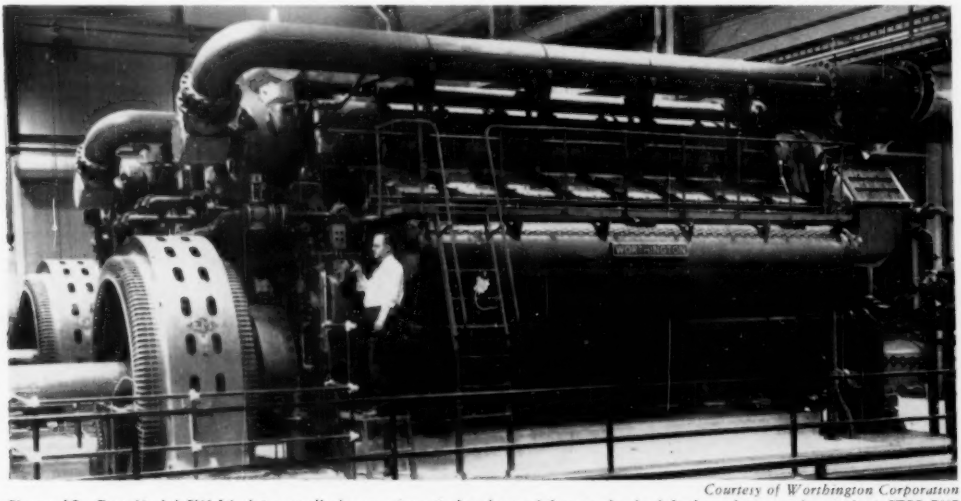


Courtesy of White Diesel Engine Div., White Motor Co.

Figure 11—Six-cylinder Superior dual fuel engine. Note twin diesel fuel and large lubricating oil filters at readers's left.

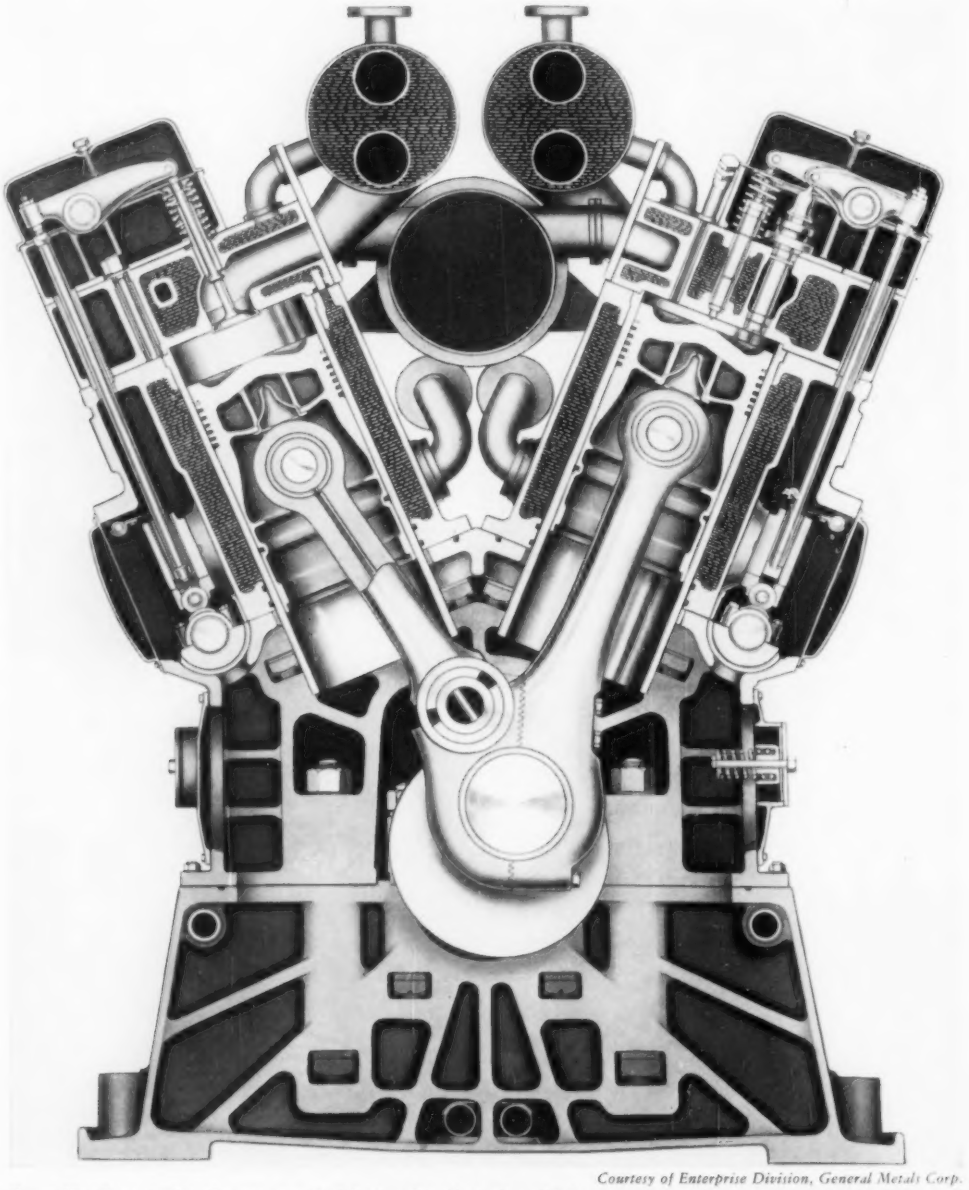
ing products of combustion or oxidation and, unfortunately, the additives in an additive type oil.

No lubrication system of any type of stationary internal combustion engine can be considered adequate unless it contains some method of cooling the crankcase oil as shown most clearly in Figure 17. If the oil temperature is allowed to go too high, oil oxidation is promoted and frequent oil changes will



Courtesy of Worthington Corporation

Figure 12—Two Model SW-14 sixteen-cylinder vee type turbo-charged four cycle dual fuel engines, each rated at 5755 BHP @ 514 RPM.

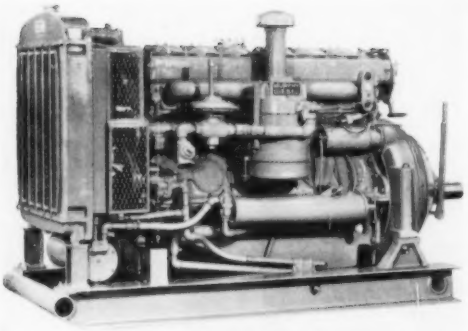


Courtesy of Enterprise Division, General Metals Corp.

Figure 13—Cross section of a vee type dual fuel engine. Note pilot oil injector and gas valve in the right-hand cylinder and articulated connecting rod.

be necessary. On the other hand, if the crankcase oil temperature is too low, water vapor from the products of combustion will condense and produce low temperature sludge. Proper oil temperature also promotes good filtration.

Generally speaking, gas and gas-diesel or dual-fuel engines are easier to lubricate than comparable engines which are operated continually as full diesels. This is based on the fact that combustion is cleaner and more complete with gas as compared



Courtesy of Murphy Diesel Company

Figure 14—Skid-mounted radiator cooled industrial type six-cylinder dual fuel engine with inclosed clutch. Rated at 227 BHP.

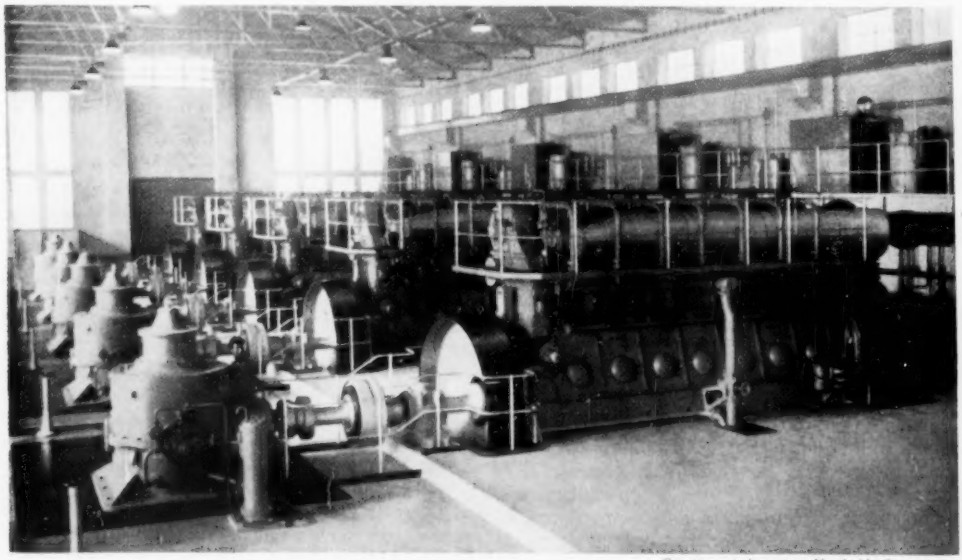
with diesel fuel. In addition, combustion temperatures are somewhat lower when burning gas as compared with operating 100% diesel. Gaseous fuel will also mix more thoroughly with air as compared with injected liquid fuel thereby permitting more complete burning. Gaseous fuels will thus produce less carbon and other partial combustion products which tend to cause plugged ports, piston deposits, ring sticking and contaminated crankcase oil.

There are a number of simple operation and maintenance items which, if followed, will materially improve the overall lubrication of gas and gas-diesel or dual-fuel engines.

1. Oil feed rate to cylinders should be kept within the limits called for by the engine manufacturer and preferably on the low side. Feeding too much oil to cylinders does not improve lubrication but only promotes ring sticking, port deposits, valve deposits and general lacquering because the excess oil has no way of getting away from the heated surfaces quickly enough. Feeding insufficient oil to cylinders will result in unnecessarily high ring and cylinder liner wear and, in extreme cases, scoring may take place.

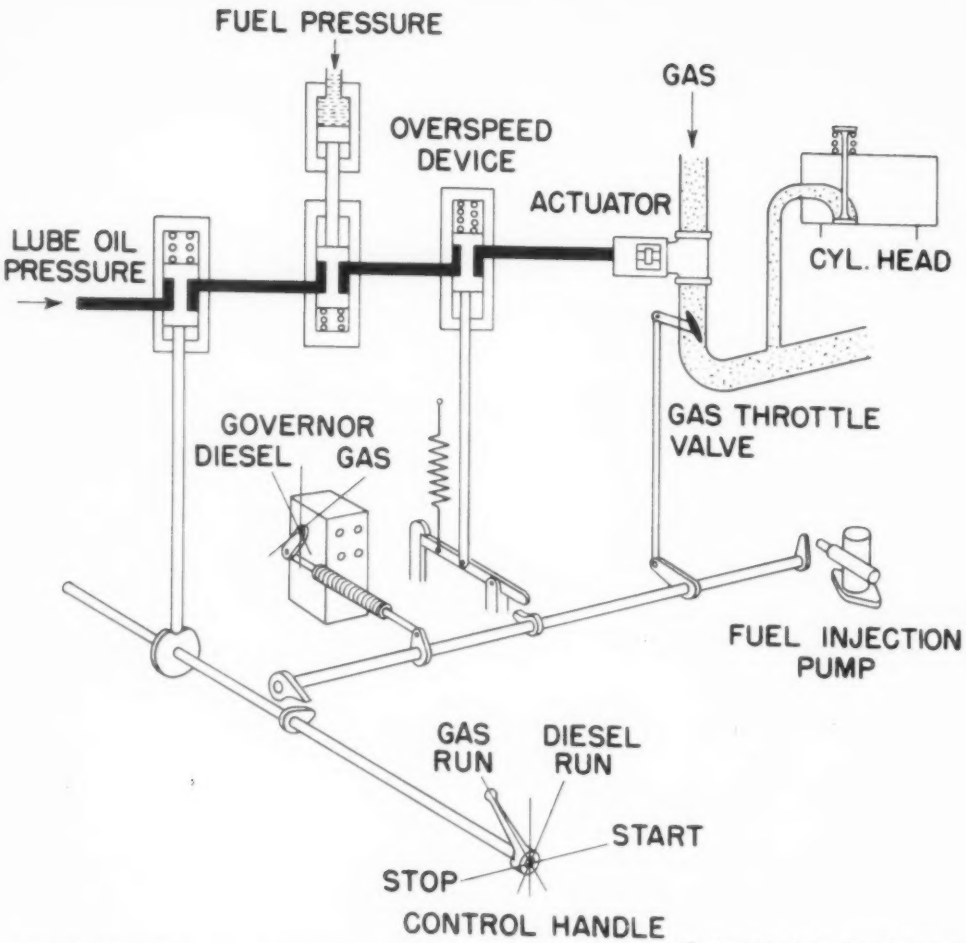
2. Forced feed lubricators should be regularly maintained. They should never be filled to more than ¾ to ⅞ of capacity in order to avoid leakage and consequent wastage of oil. Sight glasses should be cleaned as necessary and new solution installed so that operators can see at a glance that oil, at approximately the correct flow rate, is passing through to the cylinders. Check valves at the cylinders should be removed and cleaned out at least once a year in order to insure positive delivery of oil to cylinders at all times. It may be necessary to clean these check valves more frequently in cases where "used" crankcase oil is fed through the lubricators to the cylinders.

3. Natural gas should be scrubbed as dry as possible before burning otherwise, fuel valve sticking, like that shown in Figure 8, is apt to occur and needless carbon will accumulate on piston crowns and



Courtesy of American M. A. N. Corporation

Figure 15—Five seven-cylinder exhaust turbo-charged dual fuel engines, each rated 1450 BHP at 300 RPM. Together they supply Karachi, Pakistan with 144 million gallons of water each day.



Courtesy of Fairbanks, Morse & Company

Figure 16—Schematic diagram of a representative system for controlling diesel oil and gas supply to a large dual-fuel engine.

in the ring belt area. In addition, crankcase oil will be contaminated more rapidly and spark plug life also may be adversely affected.

4. Engine jacket water temperatures should be carefully watched. The inlet temperature should be maintained at a level of at least 130° F., if possible, with an outlet temperature some 10° F. higher in order to minimize the chance for low-temperature sludge to accumulate in the crankcase and other cool portions of the engine. A temperature level somewhat higher than 130° F. is desirable where water condition permits. In areas where hard or saline water is all that is available, chemical treatment should be carried out to prevent scale formation or salt deposits in oil coolers and water jackets, particularly around valves and cylinder liners.

5. For best crankcase oil service, oil temperatures should fall within the range of 140-180° F. Operating with temperatures much below this level is undesirable, not only because of the possibility of forming low temperature sludge, but also because the efficiency of oil filters drops off rapidly as oil temperatures are lowered. This is particularly true of filters or purifiers using adsorbtive materials like fullers earth for filtering purposes. On the other hand, operating with too high an oil temperature is not good for the oil: oxidation and oil thickening or viscosity build-up is accelerated. Piston-cooling oil passages must be open to insure positive oil flow at all times, otherwise the oil will carbonize in the piston head cavity, impair heat transfer and unnecessarily deteriorate the crankcase oil. Oil cooler

condition should be investigated if crankcase oil temperatures climb appreciably above 180°F. level.

On most engines, the crankcase is maintained under a slight vacuum in order to prevent leakage of oil from around the crankcase base and crankcase doors and to remove combustion contaminants which hasten oil deterioration. It is important that the vacuum be slight (perhaps ¼-½" of water), otherwise, excessive oil (and oil vapor if crankcase oil temperatures are unusually high) will be pulled out of the crankcase into the scavenging system. Not only is high oil consumption the result but also, if there is no trap in the scavenging line, carbonaceous deposits will form in the scavenging ports, as well as in the combustion chamber. There is also the possibility of causing piston rings to stick. Another consideration is the fact that crankcase explosions are less apt to occur under conditions of low crankcase vacuum as compared to high crankcase vacuum.

7. Adequate and efficient purification of oil is most important. The type of filtration and period between filter changes depends upon the type of oil used, as well as numerous other characteristics of the engine and operating variables. The petroleum lubrication engineer is acquainted with the characteristics of the oil recommended and he is in a position to suggest type of filtration, frequency of filter changes and frequency of oil changes. In very large engines the condition of the crankcase oil should be checked by a competent laboratory at regular intervals for contamination and degree of oxidation. Such analyses are not only quite involved but require interpretation by experts in this field: with proper recommendations however, they furnish valuable assistance to operators in obtaining economical operation.

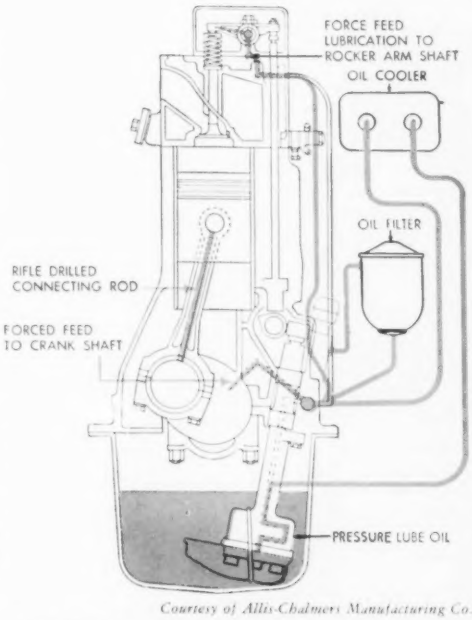
Lubricating Oil

Two general types of oil are used to lubricate gas, gas-diesel and dual-fuel engines. For the smaller, high-speed engines, where oil temperatures are relatively high and crankcase capacities are relatively small, the "heavy-duty" type oil is preferred. Such oils contain chemical additives which improve oxidation stability, dispersion and detergency characteristics. Engines requiring the use of heavy-duty oil, and lubricated with this type of oil, will remain cleaner, will require less maintenance and will operate more efficiently over a longer period of time than when lubricated with other types of oil. Certain of the heavy-duty oils also possess the property of rust prevention which is particularly desirable for engines operated in intermittent or seasonal service.

Lubrication of the larger, slow and medium speed engine depends considerably upon the type of operation, maintenance practices, auxiliary equipment, engine type and operating practices desired by management. Again the experience of a competent petroleum engineer is desirable in evaluating these items and recommending the best type of lubricant for the particular units involved.

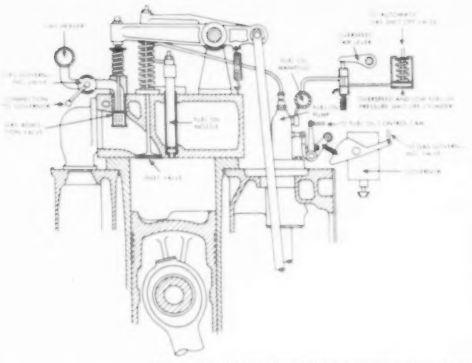
In many of the larger installations, straight mineral oils have been used very successfully. This is particularly true where the engines are being operated with relatively mild loading and good filtration equipment and change practices are followed by management. As a matter of fact, in some cases with activated type filters, very long drain periods have been used with a minimum of maintenance required as a result of ring sticking, port deposits, or cylinder or ring wear.

On the other end of the scale, there are other units being operated under overloaded conditions where management is reluctant to purchase expensive filtration equipment and follow through the necessary high rate of filter changes. In these cases the use of a detergent oil will minimize oxidation products and keep in suspension products of partial combustion, oil oxidation products, soot and small dust particles. Under these conditions, instead of purifying the oil by filtration, the contaminants are removed from the engine by relatively frequent oil drains. With the increased use of detergent oils in the newer high output turbocharged engines, new problems have arisen which generally require



Courtesy of Allis-Chalmers Manufacturing Co.

Figure 17—Schematic diagram of a complete single-lubricant pressure oiling system in a small Buda engine. Note bypass type oil filter and oil cooler.



Courtesy of Nordberg Manufacturing Company

Figure 18—Schematic diagram of a mechanism for controlling diesel pilot oil and gas supply to a large dual fuel engine. Note engine cutoff devices for overspeed and low fuel oil pressure.

explanation to the operator who has been used to lubrication with straight mineral oils. With detergent oils there is bound to be a re-distribution of engine deposits which may be baffling to some operators. There is usually an increased tendency for deposits to build up on the piston crown, on the combustion chamber walls and on the spark plug. With properly designed gas engine oils these deposits are minimized and do not affect the operation of the engine.

As mentioned previously, a number of operators are obtaining good over-all performance by using a good quality straight mineral oil. For this purpose the usual recommendation is a highly refined distilled paraffin base oil. In order to prolong its useful life the oil should be filtered or purified through an activated medium, such as fullers earth or alumina, to remove contaminants and products of oxidation as promptly as they accumulate. One of the main reasons for recommending highly paraffinic distillate type oils is to minimize the problem of thickening or viscosity build up.

When using heavy duty oils in gas engines, gross contaminants are usually removed from the system by frequent oil draining. Active type filters are usually not recommended since they may also remove a certain amount of the detergent and other additives. As an economy measure, it has been determined that it is practical to use contaminated crankcase oil in the cylinder lubrication system, where a good portion of it is consumed in the combustion chamber and/or eliminated out of the exhaust ports. In this procedure, used oil is constantly being removed from the crankcase and is being replaced by new oil, thus it may be possible to lengthen oil drain periods. Instead of doing this on a continuing basis, some operators prefer to drain the used crankcase oil at one time and store this material in separate tankage for later use as a cylinder lubricant. Of course, the used lubricating oil should be refiltered before it is added to the cylinder lubrication system to assure that contaminants with large particle size will not impair the operation of the mechanical lubricators.

SPARK PLUGS

Due to the inherent characteristics of natural gas, investigators report that substantially more energy is required for ignition than for other heavier hydrocarbon fuels like gasoline and diesel fuel. This necessitates the use of a more intense spark. For this reason gas engine spark plugs generally have large electrode surfaces so that they will not burn too rapidly.

SUMMARY

Since the last war, the production and utilization of engines capable of burning gas or a combination of gas and liquid fuel have increased at a phenomenal rate. This is the result of the tremendous expansion of natural gas transmission to many parts of the country.

Generally speaking, gas and gas-diesel or dual-fuel engines are easier to lubricate than comparable engines which are operated continuously as full diesels.

Adequate and efficient purification or filtration of oil is most important. The type of filtration and period between filter changes depends upon the type of oil used as well as numerous other characteristics of the engine and operating variables. A qualified petroleum lubrication engineer is acquainted with the characteristics of the oil recommended and he is in a position to suggest the type of filtration, frequency of filter changes and frequency of oil changes.

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1) What's an early telltale symptom of worn fuel injector nozzles?

2) What's a simple test for improperly equalized fuel injectors?

3) What's the single most important type of preventive maintenance of diesel fuel injectors?

4) What's wrong with a diesel that has a very smoky exhaust and heavy soot deposits in the crankcase oil?

5) What type of lubricant works best in diesels with trunk-type pistons?

6) In what type of diesels are straight naphthenic oils more desirable than heavy-duty additive oils?

7) What special chemical property is desirable in the lubricant for an engine that runs on high-sulfur-content fuel?

8) How do you choose between heavy-duty detergent oil and straight mineral oil in lubricating big diesels?

These eight questions cover some of the problems discussed in Texaco's factual *Diesel Data* series. They're typical of the ins-and-outs of diesel operation and maintenance that *Diesel Data* talks about, and the right answer to each one is a useful nugget of information that can contribute toward real savings in the long run.

Don't fret if you can't answer all the questions. We'll be glad to send you copies of the two *Diesel Data* fact sheets from which these questions were drawn. Write to Texaco Inc., 135 East 42nd Street, New York 17, N. Y.

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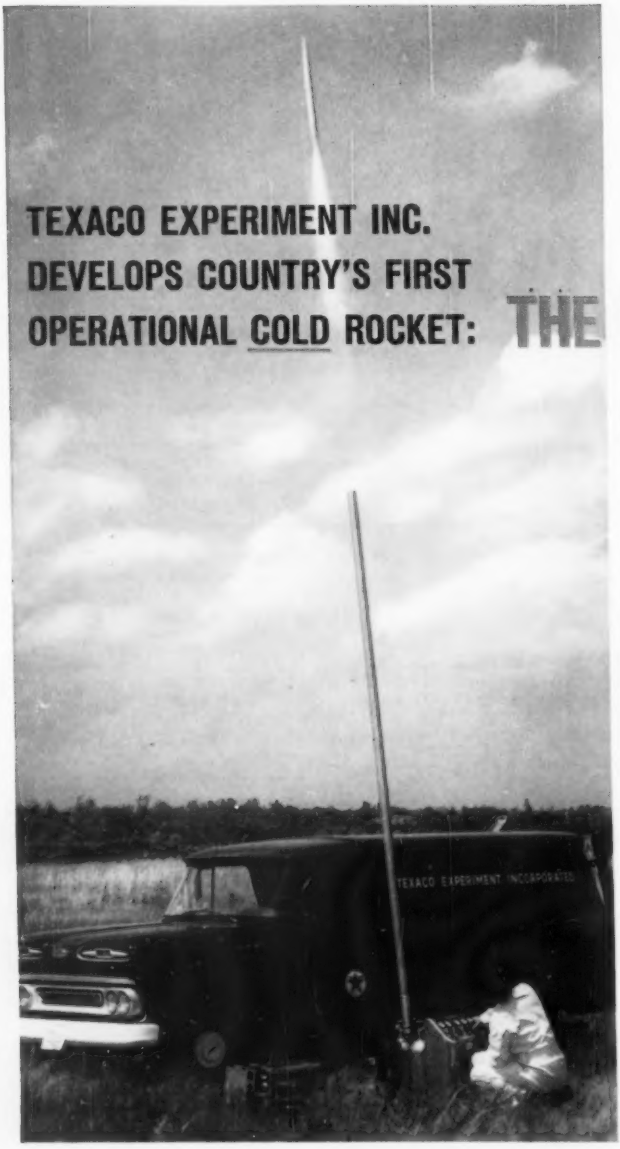

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